Appendix E

Fate and Transport Analysis Summary

Background

The fate and transport of dissolved contaminants was examined for the Inboard Area sites selected for the institutional control alternative. Proposed institutional controls involve preservation of existing cover or placement of new cover material over areas where it is necessary to protect human health and the environment from exposure to contaminants in soil. Material imported and used as cover to protect from contamination will exhibit similar physical characteristics as existing site soils. A fate and transport analysis was completed to determine the depth of cover necessary for needed protection. The analysis concluded that one (1) foot of cover would prevent exposure to receptors at all sites.

Model Application

Fate and transport mechanisms consist of advection and diffusion. Advection transport was modeled using the traditional Darcy's equation with site specific parameters as input. Advection can be described mathematically as $v=K*i/n$ where v is the groundwater velocity, K is the hydraulic conductivity, i is the gradient, and n the porosity. Values utilized included 0.003 ft/day for K (average site-wide horizontal value), 0.002 ft/ft for i (average site-wide horizontal component of the gradient), and a porosity of 0.33 was chosen (average site-wide value). Advection was determined to be 1.82×10^{-5} ft/day using Darcy's equation. This means for a typical Inboard site, it takes an estimated 151 years for groundwater to travel one foot. Under typical conditions of low groundwater gradients and very low hydraulic conductivities, transport of contaminants by advection is extremely slow and not a significant component of contaminant migration for the Inboard sites.

Where advection transport is negligible, diffusion transport mechanisms are the most important component of hydrodynamic dispersion. Diffusion can occur in any direction and is primarily driven by the chemical concentration gradient rather than ground water flow direction. Because diffusion is omni-directional, a one-dimensional model is all that is needed to predict transport in any given direction of interest. A one-dimensional form of the advection-dispersion equation was solved for BRAC site conditions (Groundwater, Freeze and Cherry, 1979). Conservative assumptions such as no degradation and constant source concentration were incorporated. Essentially, the resulting equation reduces to Fick's second law. The Fick's model states that $C/Co=erfc(x/2*SQRT(D*t/R))$, where C/Co is the ratio of concentration to initial concentration (or normalized concentration), erfc is the complementary error function, x is distance, SQRT is the square root, D is the diffusion coefficient, t is time, and R is the retardation coefficient. The retardation coefficient accounts for adsorption of contaminants to soil, thus retarding contaminant migration rates. There is no retardation when R=1. Contaminants such as pesticides, polychlorinated biphenyls, polynuclear aromatic hydrocarbons, and others typically encountered at the Inboard Area sites have R values ranging from 1,000 to over 100,000. The equation models diffusion and

C/Co represents breakthrough. Breakthrough can be defined as a normalized contaminant concentration at a given time and location, or simply the arrival of contaminants at some distance in the future. This normalized value can be compared to contaminant levels at specific sites to determine what concentration is likely to exist at a chosen distance and time. For example, if 0.3 m (approximately one foot) is chosen for a distance, 30 years for time, and using values of $D=1.65 \times 10^{-10} \, m^2/sec$ and $R=100$, then the model predicts that C/Co is 6.4×10^{-8}. This result can then multiplied by an actual observed concentration to predict a site concentration for a desired time and distance (or thickness) of concern. The predicted site concentration can then be compared to target concentrations.

Model Results

Diffusion is the dominant transport mechanism for contamination located at the Inboard Area sites. Conservative assumptions (constant source and no degradation) were made and the mathematical modeling determined that one (1) foot of cover would prevent exposure to receptors at all sites to be addressed by the application of cover.

References

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